



# Modeling executive functions in the prefrontal cortex

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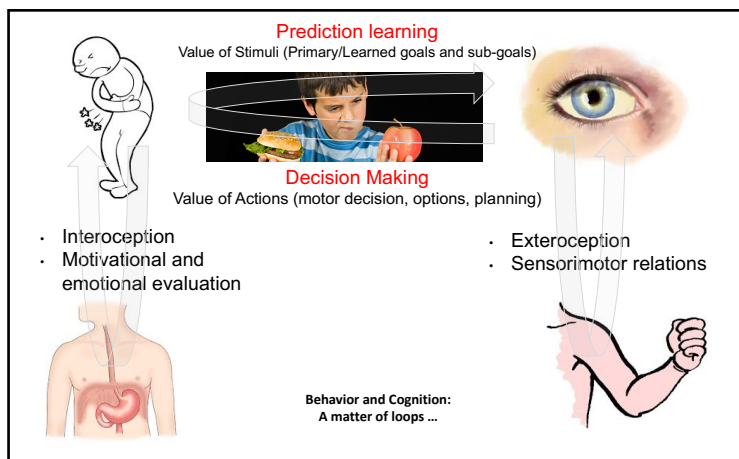
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DEFINING EXECUTIVE CONTROL FOR A COGNITIVE AGENT IN ECOLOGICAL CONDITIONS, BY **AUTONOMOUS LEARNING**

- ROLE OF THE LOOPS BETWEEN THE **FRONTAL CORTEX** AND THE **BASAL GANGLIA** FOR **PREDICTING VALUES, DECISION MAKING AND PLANNING**
- THE **LIMBIC LOOPS** DECIDE FOR THE GOAL AND THE ACTION
- THE **ASSOCIATIVE LOOPS** BIAS THE DEFAULT BEHAVIOR
- THE **MOTOR LOOPS** EXECUTE THE BEHAVIOR
- **FORWARD MODELS** ASSOCIATED WITH LIMBIC AND ASSOCIATIVE LOOPS
- THE **TASK SET**, POWERFUL CONCEPT TO DESCRIBE THIS PROCESS

## AUTONOMOUS LEARNING

### WE DEFINE OUR GOALS BY OURSELVES :

- DETECTION OF PRIMARY REINFORCERS
- LEARNING OF SECONDARY REINFORCERS
- ATTENTIONAL PROCESSES

### WE HAVE A MOTIVATION TO ACT :

- FUNDAMENTAL NEEDS
- INTRINSIC MOTIVATION
- GOAL-DRIVEN BEHAVIOR

### WE SELF-EVALUATE OUR PERFORMANCES :

- META-CONTROL

### WE ASSOCIATE DIFFERENT KINDS OF LEARNING AND INFORMATION REPRESENTATION :

- CUES
- ABSTRACTIONS
- EPISODES
- WORKING MEMORY

### WE CUMULATE AND RE-EXPLOIT PREVIOUSLY LEARNT KNOWLEDGE AND STRATEGIES IN DIFFERENT CONTEXT :

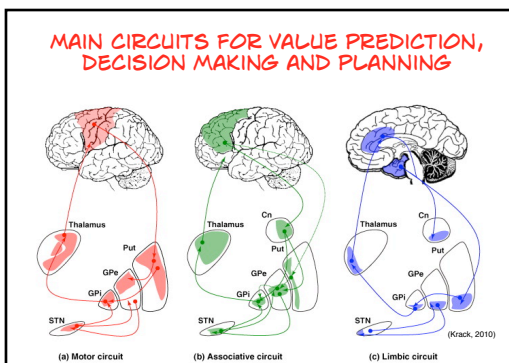
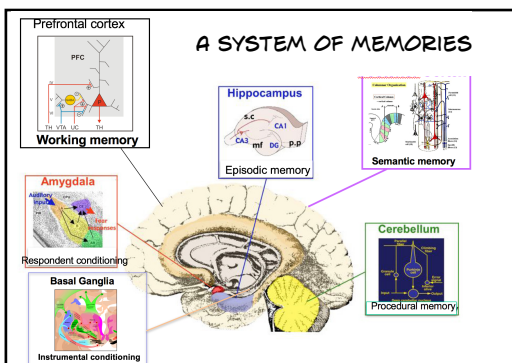
- LIFE-LONG LEARNING AND TRANSFER LEARNING

### WE ADAPT EVEN IF THE WORLD IS CHANGING AND UNCERTAIN :

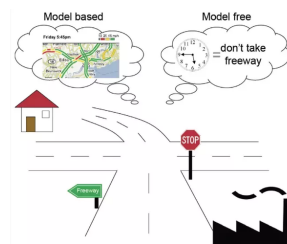
- STOCHASTICITY AND VOLATILITY

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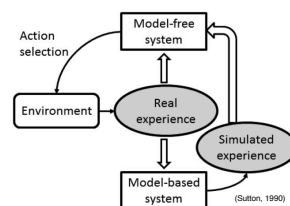
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## MODEL-BASED AND MODEL-FREE REINFORCEMENT LEARNING



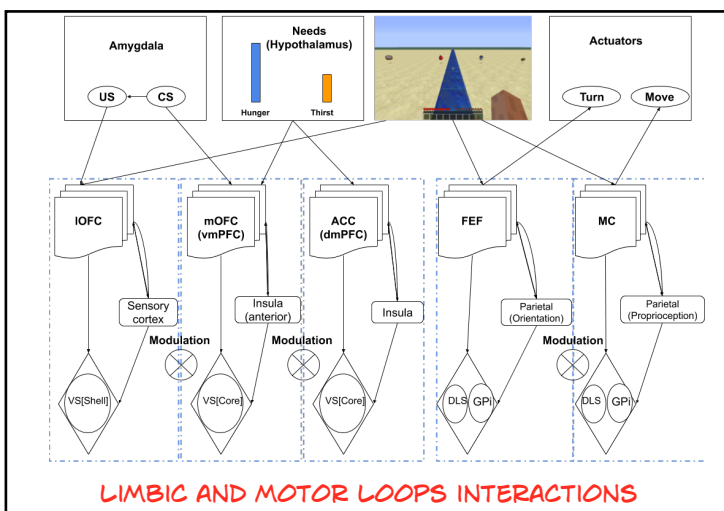
- **MODEL-FREE (MF):** LONG TO LEARN, COMPACT
- **MODEL-BASED (MB):** USE **FORWARD MODELS**, MORE FLEXIBLE BUT HEAVY TO COMPUTE
- WITH **FORWARD MODELS**, **GOAL-DRIVEN STRATEGIES** MORE TRACTABLE THAN **STIMULI-DRIVEN STRATEGIES**



- MF CONTROLS THE BEHAVIOR
- MB TRAINS MF BY REPLAYS (RETROSPECTIVE MEMORY) AND SIMULATIONS (PROSPECTIVE MEMORY)

## ROLE OF THE **LIMBIC LOOPS** : FORAGING OR DECISION BETWEEN SEVERAL TARGETS ?

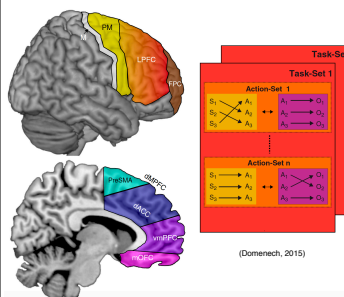
- **LOFC:** **LEARNS VALUES** OF STIMULI (PAVLOV); MENU DEPENDENT; SENSORY REPRESENTATION OF REWARDS; CONSUMMATORY BEHAVIOR, MODEL BASED; SELECT THE BEST TWO OPTIONS
- **MOFC:** REWARD REPRESENTATION FOR PREPARATORY BEHAVIOR (OPERANT, MODEL FREE), INTEGRATE LEVELS OF NEED; VALUE DIFFERENCE SIGNAL; **DECIDE FOR THE GOAL**
- **ACC:** INTEGRATE COST OF EFFORT TO **DECIDE FOR THE ACTION**; INVERSE VALUE DIFFERENCE SIGNAL; IF STRONG SIGNAL OF CONFLICT, ASK FOR A SWITCH
- **FEF:** **ORIENTATION TOWARD THE GOAL**
- **MC:** **MOVE FORWARD** FOR GOAL CONSUMPTION



## TASK SET

SET OF REWARDING S-R ASSOCIATIONS LEARNED IN THE SAME CONTEXT

- USE THE DEFAULT TASK SET, OR SWITCH OR CREATE A NEW ONE
- EXOGENOUS CONTROL (COMPETITION FROM STIMULI)
- ENDOGENOUS CONTROL (BIASING FROM GOALS)



## ASSOCIATIVE LOOPS : BIAS THE DEFAULT BEHAVIOR

TOP-DOWN CONTROL OF BEHAVIOR BY PFC AND HIPPOCAMPUS

- PFC CAN BIAS COMPETITION FOR NON-DOMINANT BEHAVIOR
- ROLE OF LPFC FOR WORKING MEMORY AND ATTENTIONAL PROCESSES
- THE HIPPOCAMPUS CAN RAPIDLY BIND ARBITRARY REPRESENTATIONS NOT YET FORMED IN THE CORTEX
- EXPLICIT REPRESENTATION OF EPISODES AND REPLAYS
- DEFINE SUBGOALS (INTENTIONS, MEANS) AND THOUGHTS (COVERT ACTIONS ENCODED BY THEIR PERCEPTUAL EFFECTS, FORWARD MODELS)

